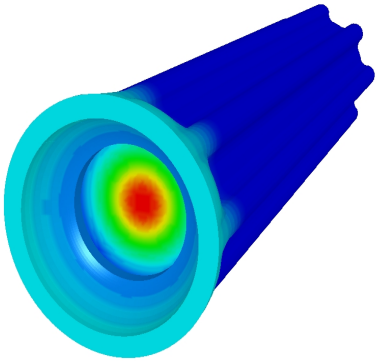
THB Workshop, BNL, July 23rd, 2014

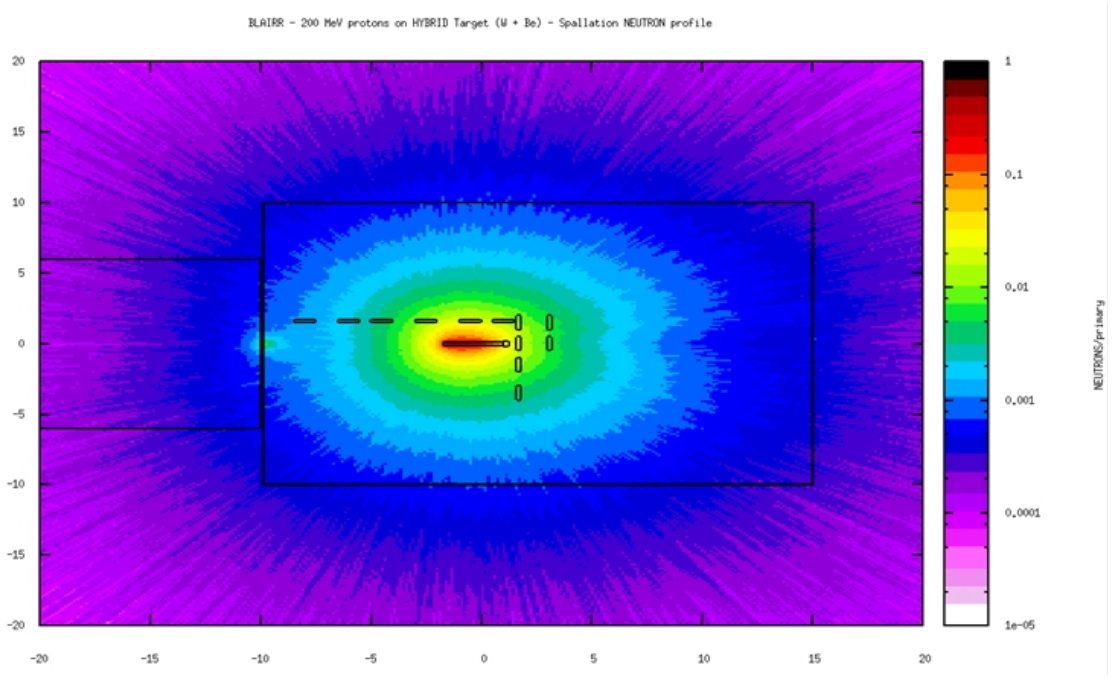
- **ADSR/Spallation Target R&D Session**

SUMMARY

N. Simos, F. Méot, BNL

BLAIRR Target: 200 MeV Protons on W Target with Be Shroud





OBJECTIVE OF THE ADS-R/Spallation target R&D SESSION:

Hear thoughts from the community on relevant beamline activities addressing one or more issues that are of direct or indirect relevance to ADSR

Keeping in mind :

- **Goals**
  - **Identify and/or begin to construct a user community**
  - **Establish approximate parameters for (a) beamline(s),**
  - **including energy, intensity, time structure,**

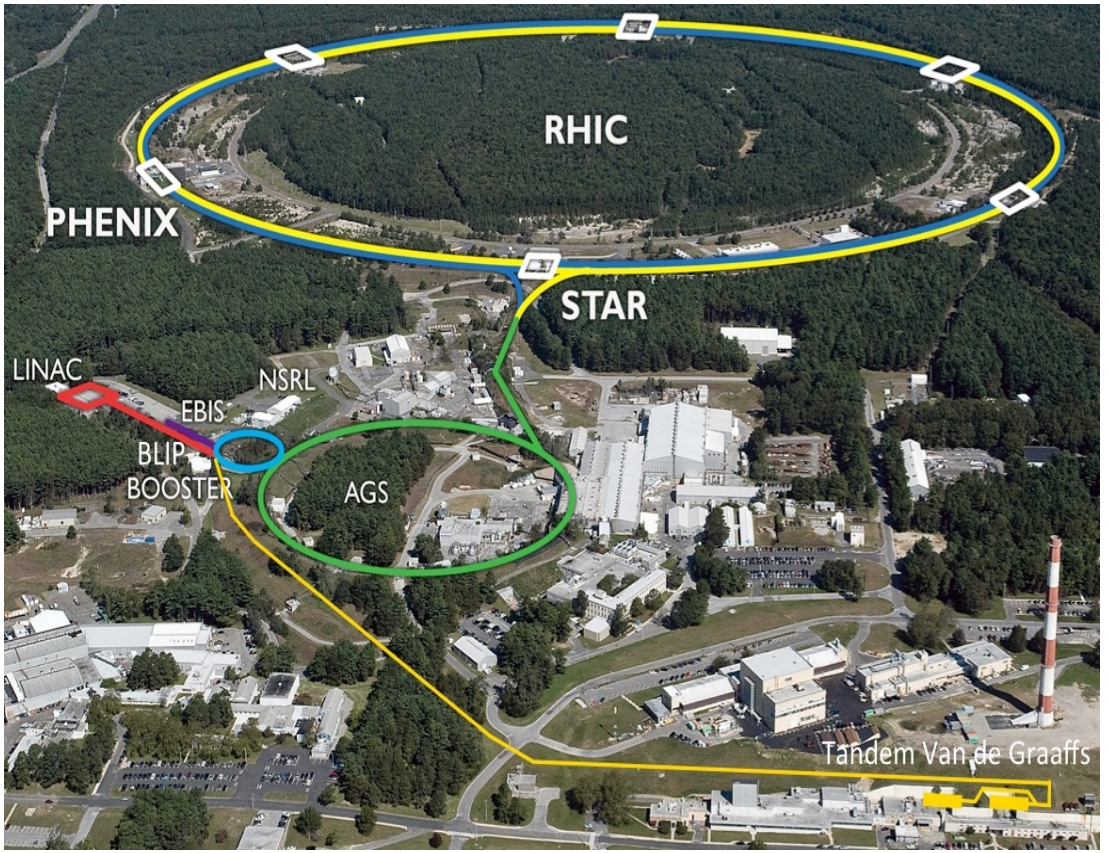
- **Deliverables**
  - **Working group summary report (Closing Plenary)**
  - **Beam parameters spreadsheet**

Topology Possibilities

LINAC
200MeV/30kW

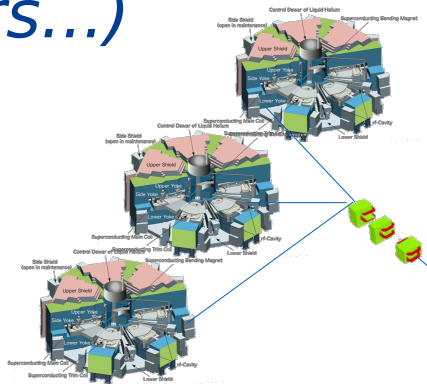
Booster
0.2-1.5
GeV/30kW

AGS
1.5-23 GeV/100kW



[R. Tribble / Plenary, Mo]

- **ADS-R/Spallation target R&D projects at BNL could be seen as part of broader ambitions**
- Inter-directorate BNL collaboration to develop a dual role hybrid accelerator driven system *(LDRD, DP and other RFI affairs…)*

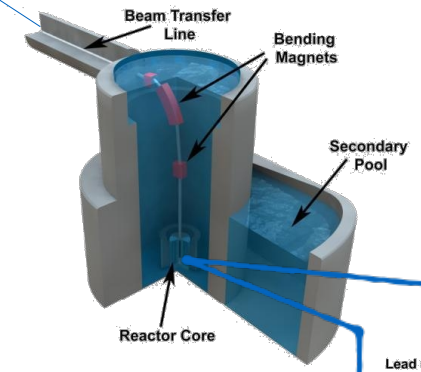


Burning nuclear waste while delivering carbon neutral energy

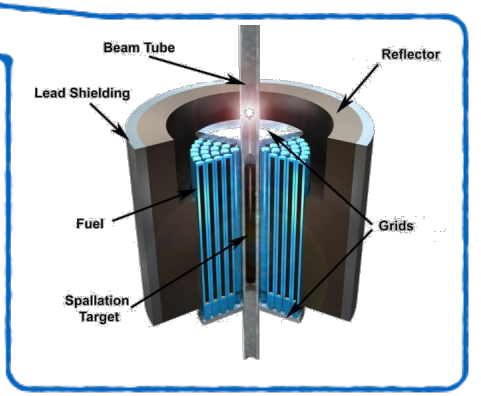
F. Meot (C-AD), N. Brown (NSTD), D. Brown (NNDC)

Accelerator Stewardship Program is seeking ***new roles for accelerator science*** in energy and environmental applications *(Federal Register, 79, p 21910, April 18, 2014)*

- Development of *sustainable nuclear fuel cycles* to meet growing global energy demand with low-carbon energy sources
- **Burn higher actinides and long-lived fission products from LWR spent nuclear fuel**
- ***Produce carbon neutral energy while load-following the grid***
- **Design for passive safety**



Ongoing multi-laboratory DOE study has identified 19 fuel cycles for future R&D investment out of 4000+ considered, ***5 of these promising fuel cycles leverage the potential of accelerator driven systems*** *(Wigeland, Taiwo, et al. Proc. Of ICAPP 2014)*



[H Abderrahim / Head of MYRRHA] MYRRHA SpallationTarget Design and Qualification R&D Programme

- **Notable impact of experimental R&D : validated the 'window' option / MW class object**

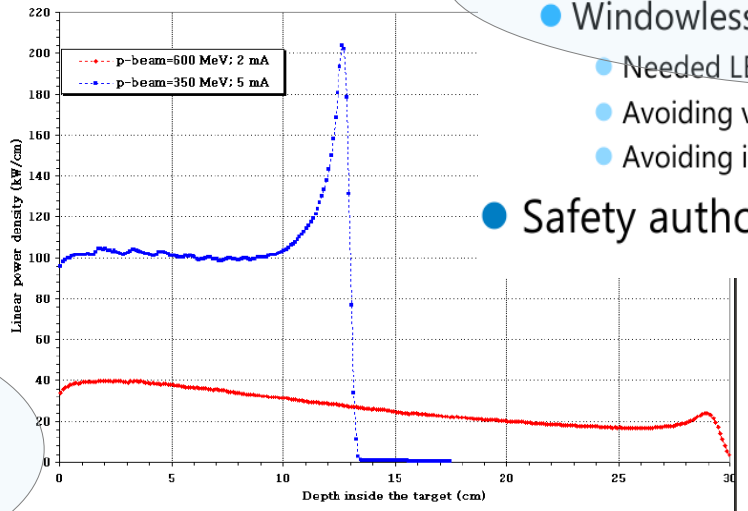
MYRRHA spallation target evolution from windowless to window design

- MYRRHA accelerator technology & beam characteristics
  - Cyclotron (1998 ➔ 2002) towards LINAC (2003 ➔ ...) ➔ windowless
  - 350 MeV*5 mA (... ➔ 2008) (windowless) ➔ 600 MeV*2.4 mA ➔ window (2009)
  - Current density > 50 µA/cm^2 (till 2008), no window material can survive ➔ 600 MeV*2.4 mA ➔ window (2009)
- Spallation loop geometry simplification ➔ window (2009)
  - Windowless needed a separate loop to guarantee:
    - Needed LBE flow
    - Avoiding volatile spallation products leaving the free surface to the beam line
    - Avoiding interaction of proton beam with LBE in recirculation zone
- Safety authority requesting the window a barrier

Proton Energy changed from 350 MeV

- Ip reduced
  - Impact current density on window
  - Impact power density
- FA enlarged
  - Impact current density
- Window target design becomes thinkable
- MEGAPIE exp. Promising results

Go Window !



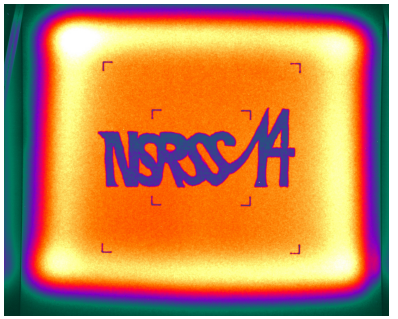
[H Abderrahim / MYRRHA]

A source of inspiration for our beamline projects

MYRRHA Window spallation target R&D programme

- Feedback experience from MEGAPIE (design, LBE control, material testing, spallation products inventory)
- Material irradiation in BR2 (MTR, Mol, BE) and in BOR-60 (FR, Dimitrovgrad, RU)
- Window coolability in JLBL-3 loop at JAEA (Tokai, JP)
- Fuel scale Thermal-hydraulic and mechanical testing in COMPLOT loop at SCK•CEN (Mol, BE):
  - Flow control,
  - Erosion control,
  - Coolability,
  - Flow induced vibration
- Volatile spallation products control and mitigation
- Beam footprint shaping and control

[Sivertz / testBL, Mo]
NSRL beamline



ADS Applications/Issues/Challenges

Guidance to ADSR targetry/spallation R&D programme

- **Accelerator:**
  - **Most applications require a high power accelerator in the range 5 – tens of MW beam power**
  - **High reliability and CW operation desirable/essential**
- **Target/Window:**
  - **Must be able to handle high power densities**
  - **Materials and geometry should maximize leakage of neutrons for "productive" use**
  - **Reliability, Maintainability, Inspectability, and Maintainability (RAMI) considerations crucial**
- **Applications:**
  - **No "killer app" for ADS has been identified**
  - **Several potential roles have been identified with varying demands implied**
  - **For energy production or meaningful transmutation, sub-critical blanket is essential**

[M. Todosow]

More regarding ADSR targetry can be found in the "OS White Paper"

Accelerator and Target Technology for Accelerator Driven Transmutation and Energy Production

H. Aït Abderrahim[h], J. Galambos[d], Y. Gohar[a], S. Henderson[c*], G. Lawrence[e], T. McManamy[d], A. C. Mueller[g], S. Nagaitsev[c], J. Nolen[a], E. Pitcher[e*], R. Rimmer[f], R. Sheffield[e], M. Todosow[b]

[a]*Argonne National Laboratory*
[b]*Brookhaven National Laboratory*
[c]*Fermi National Accelerator Laboratory*
[d]*Oak Ridge National Laboratory*
[e]*Los Alamos National Laboratory*
[f]*Thomas Jefferson National Accelerator Facility*
[g]*CNRS-IN2P3, France*
[h]*SCK•CEN, Mol, Belgium*
[*]*Co-chairs*

September 17, 2010

Finding #12: Spallation target technology has been demonstrated at the 1-MW level, sufficient to meet the "Transmutation Demonstration" mission.

Finding #13: With appropriate scaling at each step along a technology demonstration path, there are no obstacles foreseen that would preclude the deployment of spallation targets at a power level (10 to 30 MW) needed to meet the application of ADS at an industrial scale.

Finding #14: Technology is sufficiently well developed to meet the requirements of an ADS demonstration facility; some development is required for demonstrating and increasing overall system reliability.

Finding #15: For *Industrial-Scale Transmutation* requiring tens of MW of beam power many of the key technologies have been demonstrated, including front-end systems and accelerating systems, but demonstration of other components, improved beam quality and halo control, and demonstration of highly-

[A. Fabich / CERN] Experimental targetry at CERN

- **Considerations directly relevant to our concerns**

  - Test objects: TARGET = OBSTACLE

    interacting with the beam resulting in energy deposition:

    material damage, material vaporisation, thermal management, radiation damage, beam induced pressure waves, thermal shock

    - Benchmarking for simulations, material properties
    - Prototyping

      "Thick" targets:

      - Production targets
      - Collimators
      - Accidental exposures of beam elements (e.g. magnets)

      "Thin" targets

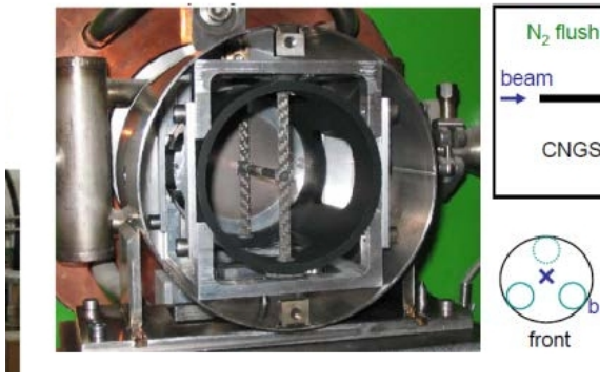
      - Beam measurement – detectors and monitors
        - Also off-beam-axis in parasitic mode (e.g. BLMs)
      - Vacuum windows/pipes
      - Collimators (bending crystals)

[A. Fabich / CERN]

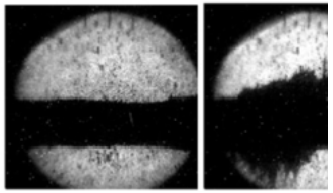
- **Broad and decades long experience in targetry at CERN**

CNGS target

› in LHC transfer line (20



MERIT – mercury target test



[A. Fabich / CERN]

- **Eventually further profiting to users communities in the form of a dedicated test facility, started 2011/2012 with a diversity of experiments**

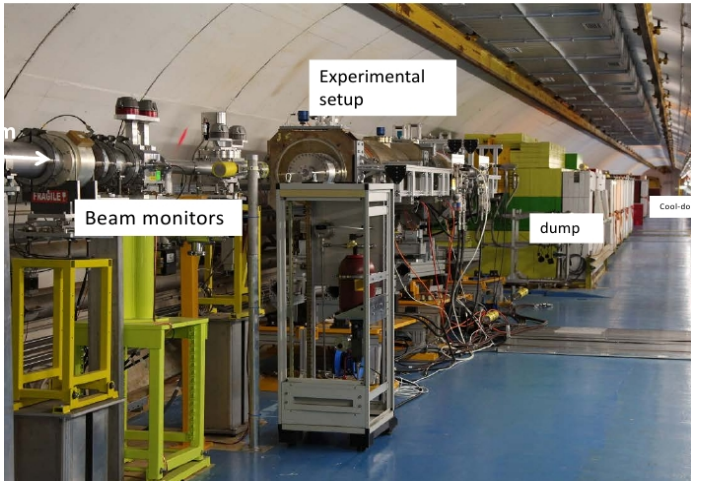
HiRadMat

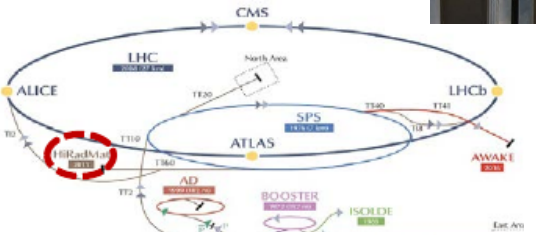
High-**Ra**diation To **Mat**erials http://cern.ch/hiradmat

- Dedicated test facility
- Protons 440 GeV, also ions possible
  - In the higher range for production targets
  - With the small focus a higher pulse intensity can be simulated in terms of pe
- Maximum $5*10^{13}$ protons per pulse
- Tests with single pulses; HiRadMat is not an irradiation facility
  - Limited to ~10^{16} protons/year
  - Reduces residual radio-activity for manipulation
- Destructive tests possible as decoupled from accelerator machine/vacu

	Proto
Beam energy	
Bunches/pulse (max)	
Pulse intensity (max)	
Bunch spacing	25, 5
Pulse length (max)	
Beam spot	
Pulse energy (max)	

Target area





Experiments in 2012

- RIB target R&D
- LHC transfer collimator (2x)
- BLM validation
- RP benchmarking
- Crystal collimation

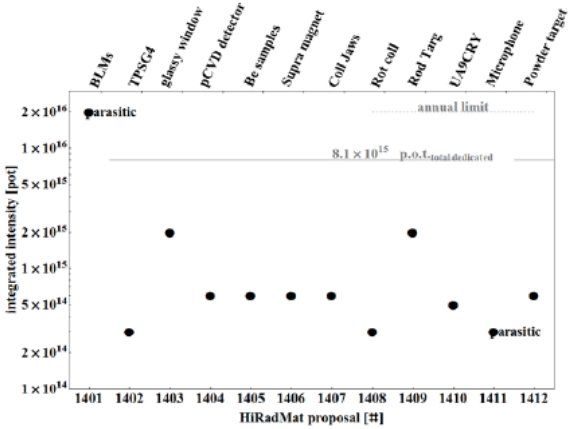
See http://cern.ch/hiradmat for links

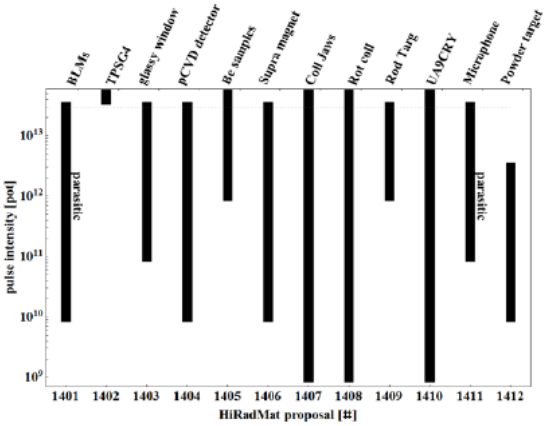
[A. Fabich / CERN]

- **And more to come... an indication that that beam line does answer existing needs !**

Proposals 2014/2015

- Call for proposals in spring 2014
  - 12 applications
- Beam run 2014/15 allows about 12 beam slots





HiRadMat receives support from the EU FP7 grant EuCARD2 within the activity "Transnational Access".

[P. McIntyre / Texas A&M] Strong Focusing Cyclotron

- **A little upstream of our preocupation, or :**

How to produce high power from a FFAG cyclotron

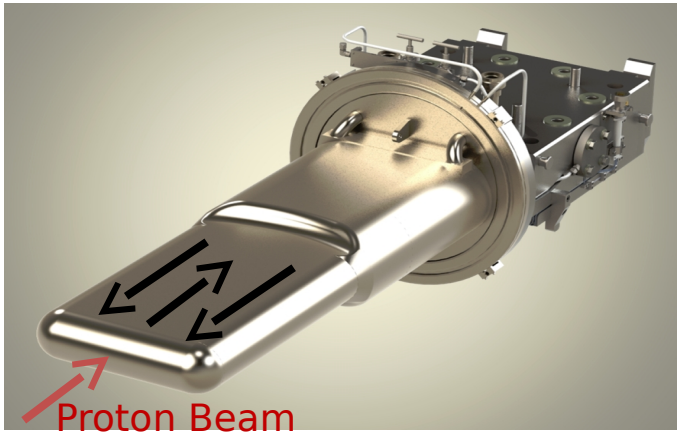
- **However in the end an impressive GeV/MW class ring design, potentially proper to feed beam to ADS-R targets !**

[M. Wendel / SNS] SNS Target R&D

Mission is focused on neutron science

1.4 MW on target, 1 GeV, μs pulses to target

at 60 Hz, plans to 2MW+ upgrade



Second target station, solid W, 500kW, planning is underway: TDR will be issued in FY15

Targetry R&D ranges from

lifetime reliability to higher

power enhancement, to

performance optimization,

cavitation damage,

irradiation effects, etc.

Finally, [S. Leray / CEA]

MEGAPIE: the world's first high-power liquid metal spallation neutron source.

Ch. Latge[1] (CEA) France (christian.latge@cea.fr), **M. Wohlmuther**[2] (PSI) Switzerland (michael.wohlmuther@psi.ch) ,

Presented by **Sylvie Leray** (CEA) France

Y. Dai[2], **D. Gavillet**[2], **A. Gessi**[3], **A. Guertin**[6], **B. Hammer**[2], **S. Heinitz**[2], **J. Henry**[1], **M. Konstantinovic**[4], **S. Leray**[1] , **R. Lindau**[5], **C. Fazio**[5], **S. Maloy**[8], **J. Neuhausen**[2], **S. Saito**[7], **K. Park**[9], **P. Roubin**[1], **K. Samec**[2], **D. Schumann**[2], **K. Thomsen**[2], **A. Türler**[2], **L. Zanini**[2], **W. Wagner**[2]

1 CEA Cadarache DEN-DTN 13108 Saint-Paul-lez-Durance France, 2 PSI Villigen; 3 ENEA Brasimone; 4 SCK-CEN Mol; 5 KIT ; 6 CNRS Subatech Nantes; 7 JAEA Tokai; 8 DOE-LANL, 9 KAERI

"TRANSFORMATIVE HADRON BEAMLINES" WORKSHOP
BROOKHAVEN NATIONAL LABORATORY
(UPTON, NEW YORK, USA)
FROM JULY 21 TO 23, 2014.

[S. Leray / CEA]

- **Irradiation at PSI 08/2006- 12/2006**

MEGAPIE EXPERIMENT

A key experiment in the ADS roadmap:

MEGAwatt PIlot Experiment (MEGAPIE) (1 MW) initiated in 1999 in order to design and build a liquid lead-bismuth spallation target, then to operate it into the Swiss spallation neutron facility SINQ at PSI .

It was to be equipped to provide the largest possible amount of scientific & technical information without jeopardizing its safe operation.

Several main challenges for the MEGAPIE project

- to design a completely different concept of target in the same geometry of the current spallation targets used at PSI.

- to develop and integrate two main prototypical systems : a specific heat removal system and an electro magnetic pump system for the hot heavy liquid metal in a very limited volume.

- to design a 9Cr martensitic steel (T91) beam window able to reach the assigned life duration.

- to license a LBE in relevant conditions

- to operate a LBE target

- to develop the decommissioning strategy and waste management

- to characterize LBE and structural material (PIE)

[S. Leray / CEA]

Certainly a first choice source in the matter of requisites as well as objectives for possible ADSR/Spallation targetry R&D

GREAT INFORMATION!!!

The **final MEGAPIE Technical Review Meeting** (TRM) will be the last in a series of 11 meetings which were held on a regular basis during the project. In contrast to other TRMs the current meeting will be open to all interested researchers from the ADS, Material Science and Target Community and – of course – to all contributors to the MEGAPIE project.

In this TRM **the main achievements of the MEGAPIE project in the past 15 years will be reviewed** and – in a combined session with IWSMT – **the latest Post Irradiation Examination (PIE) results will be presented for the first time.**

Moreover, **one session will be devoted to current ADS projects**.

Drawn from [Ramberg / testBL, Mo] :

Tips for a Test Beam Manager :

It has been my experience [from light sources - FM] that

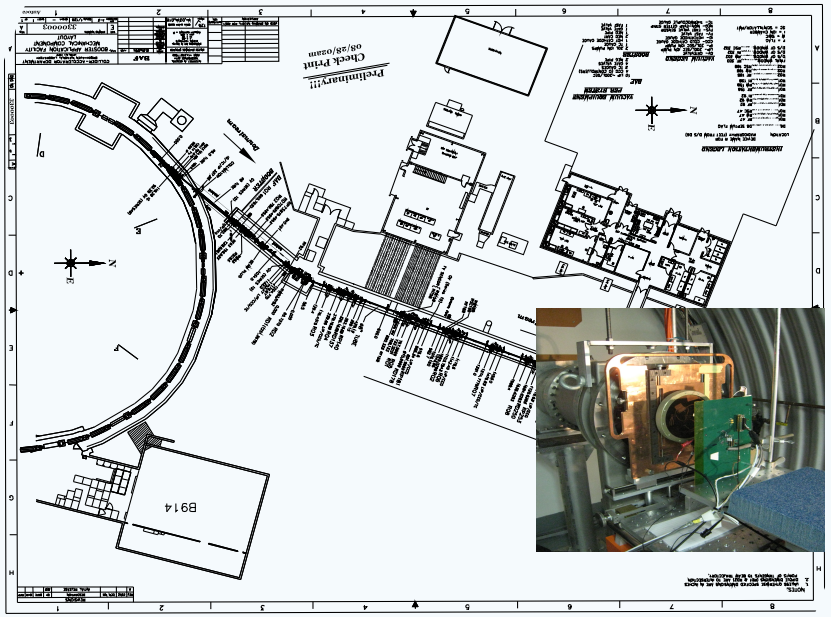
“If you build it, they will come!”.

[Plan on] incremental improvements

COMMENTS

What we (may) have in mind in the matter of ADSR/spallation dedicated beam line would probably not look very different from NSRL beamline

[Sivertz / testBL, Mo] NSRL Beamline Design



NSRL Beamline designed to be achromatic with a series of 9 quads, 10 steering/pitching dipoles, and a pair of octupoles to produce a large bowl-shaped intensity distribution suitable for radiobiology experiments.

21 July 2014

COMMENTS

- There are common interests with n-TOF hardware, however,

[Aberle / n-TOF, Tue]
research fields of interest at n_TOF concern nuclear data

whereas, [Danon / n-TOF, Tue]
reactor design is a combination of geometry and nuclear data calculations.

A dedicated beamline may require more flexibility in equipments, detection systems...

COMMENTS

From N-TOF discussion - the question of maximum beam energy (beyond booster, need AGS ?) was raised

(Reminder, booster hypotheses : 1.5GeV, 6.67Hz, 1.e14ppsec)

- H Abderrahim :
  - optimum energy is between 800MeV and 1GeV
  - Gain from n multiplicity is not worth compared to issues resulting from higher E

  Booster type of energy thus fine in that frame of ADSR T/S R&D activities.

- More discussions :

- Bob C.: There may be interest in transmutation studies at very high energies, based on long targets, 24 GeV from AGS in that respect could be explored

- High energy also has relevance with S. Leray's n-TOF talk “high energy nuclear data” and other high energy spallation residues studies

- On the other hand AGS can bring low energy beam from booster (down to 500 MeV – cf muSR R/D, less ?) to former “AGS experimental areas”. Connection equipment is preserved there, close to ~100% TBC, resurectable.

COMMENTS

From ADSR/spallation T discussions

- Plan both solid and liquid targetry R/D

- Recommendation on experimental R&D towards ADSR target : Radiation damage.
  Extend capabilities – BLAIRR

- Question to HA : Would MYRRHA be interested by ADSR targetry R/D at BNL ?

Answ. : Issue is having a core. Consider possibility of zero-power core, is this feasible ?

COMMENTS

Presence of the EU project MYRRHA at THB – in the person of its director, Pr. H Abderrahim – is an opportunity to identify domains of possible collaboration between MYRRHA and BNL, the two below come out of this workshop :

- Window

- Beyond targetry/spallation beamline R&D : accelerator reliability

Confer ADSR/Spallation session, discussion [HA] :

- reliability is essential, strong constraint on beam trips >3sec in particular == beam has to follow rules of reactor == beam failure is reactor failure and results in drama == concern is that the ADSR might have long idling periods.
- Myrrha considers accelerator technology will be there by 2020, focusing on reliability.

A COMMENT PICKED FROM

5th high power atrget Workshop, FNAL

B. Riemer talk

- Integrated approaches to source design around specific instrument performance metrics, utilizing optimization techniques, can show new paths to high-performance
  - TS-2 at ISIS

- When **isn't** higher target power the right direction for higher performance?
  - Spallation sources
  - Other high-power target applications R&D

"There may be more clever ways to high neutron flux then increasing the accelerator power"